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Eidola: An Interactive Augmented Reality Audio-Game Prototype

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ABSTRACT

Augmented reality audio represents a new trend in digital technology that enriches the real acoustic environment with synthesized sound produced by virtual sound objects. On the other hand, an audio-game is based only on audible feedback rather than on visual. In this work, an audio-game prototype is presented which takes advantage of the characteristics of augmented reality audio for realizing more complex audio-game scenarios. The prototype was realized as an audiovisual interactive installation, allowing the further involvement of the physical game space as the secondary component for constructing the game ambient environment. A sequence of tests has shown that the proposed prototype can efficiently support complex game scenarios provided that the necessary advanced interaction paths are available.

1. INTRODUCTION

It is well-known that sound represents one of the most important components of a video game, since its integration with the visual output constructs the game "virtual" world, while in many cases it realizes fundamental interaction paths with the user. Extending the sound weight as a fundamental game component, during the last years, the concept of the audio-game was introduced. In an audio-game, there is no graphical environment. Instead, the game-play is based only on audio, allowing a number of specific purpose applications to be supported, such as the ability to be played by visually impaired humans [1]. Towards this aim, a number of legacy video-games have been recently augmented with specific audio techniques, for example in order to provide information about the direction and the distance of moving targets to blind people [2]. In most of the cases, these audio-augmented game scenarios are not complicated, allowing their adaptation using relatively simple rules and conditions.

Based on the above considerations, in this work, the recently introduced by other researchers Augmented Reality Audio (ARA) concept [3] is employed for realizing an interactive, augmented reality-based game prototype (or an "ARA-game", a term which to the best of the authors knowledge was not previously introduced). The purpose for experimentally demonstrating the above game prototype is to initiate the investigation on the following topic: can ARA provide the necessary framework for efficiently realizing complicated and/or advanced audio-based game scenarios?

In contradistinction with audio-games and for specific reasons that will be explained later in this text, the natural-physical space of the game is not excluded and participates in the construction of the complete game environment as its visual "ambient" component. More specifically, the proposed ARA-game prototype consists of the following components a) the real world visual environment which represents the game-play physical space b) the real world sound component which is present within the game physical space and c) the virtual audio information which is synthesized in real-time, processed and reproduced in three dimensional space. From the above components, the first two are responsible for representing the "ambient" audiovisual environment of the ARA-game, while the third one is used for dynamically reproducing the information required for realizing the desired game-play.

For the purposes of the current work, the above three components were realized and integrated within an interactive audiovisual installation termed "Eidola", a Greek word used for describing the concept of acoustic sound source images (see Fig. 1). In general, interactive audiovisual installations represent a new form for experimenting with and realizing complex human-oriented experiments that most commonly involve human-machine interactions, while they are also employed by modern artists as new artistic expression approaches [4], [5].

The rest of the paper is organized as following: In Section 2, a brief overview of ARA fundamentals is presented, focusing mainly on techniques applied for realizing ARA environments. Next, the analytic description of the "Eidola" ARA-game is provided in Section 3, followed by a brief analysis of the functional and behavioral observations made during an installation exhibition (Section 4). Finally, Section 5 concludes this work and accents further enhancements that may be integrated in future ARA games.

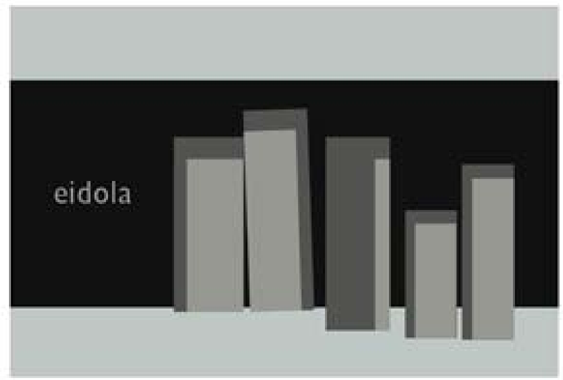

Figure 1 The "Eidola" installation logo

2. ARA FUNDAMENTALS

The ARA concept is based on the fact that a natural sound environment can be enriched with synthetic, virtual sounds (also termed as virtual audio objects) [6]. In order to ensure that the above enrichment process is accurate (mainly in terms of acoustic authenticity and natural representation of the final augmented sound environment) binaural technology [7] is employed for a) recording the natural sound environment and b) spatially representing the virtual audio components.

The natural environment binaural recording is typically performed using in-ear microphones integrated within an ARA headset [8]. The microphone signals are driven to an ARA mixer, which is responsible for mixing them with the binaural representation of the virtual sound object. For effective ARA mixer realizations, a number of issues have to be considered, such as equalization to correct the coloration caused by the leakage through the ARA headset and changed resonances in the closed ear-canal [9]. Additionally, head-tracking represents a highly-required demand, since it allows the free movement of the human participant / user, without changing the relative position of the sound sources and hence the overall spatial audible impression. Towards this aim, a number of head-tracking techniques have been already proposed [10] and employed for realizing both virtual and augmented reality applications [11].

Head-tracking combined with room acoustics simulation techniques also improves the sound localization efficiency of humans, mainly by allowing the capture of small unconscious head movements. The implementation of such a functionality raises high-quality, time-varying Head-Related Transfer Functions (HRTF) interpolation issues, with relative high computational load. In order to overcome this problem, a previously published work has proposed a virtual ambisonic approach for carrying out binaural sound reproduction in real-time [12].

Additional psychoacoustic experiments have considered the human 3D sound localization performance as a function of the azimuth / elevation angles, as well as for different virtual sound objects distribution types (typically random and regular [13]). The outcome of such evaluations should also be carefully considered when designing ARA environments.

3. PROPOSED ARA-GAME OVERVIEW

3.1. Game scenario and user equipment

As it was previously mentioned, for the initiative purposes of the current work the ARA-game play complexity was decided to be as low as possible. The game prototype scenario employed here was based on the presence of a number of invisible creatures that live within the game room. These creatures are named "Eidola". The player of the ARA-game has got the mission to enter the room and defeat all these creatures that are moving around following non-linear traces within the 3D space. In order to do so, the player has to pull a virtual trigger (i.e. press a specific button) when his/her position coincides (within a fixed accuracy limit) with the "Eidola" instantaneous position on the 3D-trace they follow.

The game scenario is sub served by a number of real-world objects located within the game space. These objects are also producing sounds continuously, at regular time instances or upon user interaction. The presence of these objects in the game physical space was found to be necessary in order to compose a more natural game environment and atmosphere, while they also offer a secondary feedback audiovisual path to the user, helping him/her to determine the possible "Eidola" movement boundaries. It should be noted that the volume of these objects constrain the movement of the "Eidola" creatures, forcing them to change their movement trace. A detailed list of the real-world objects selected during this work will be provided in the next Section.

In order to play "Eidola" the user has to wear the appropriate equipment (Fig. 2). This equipment consists of an ARA wireless headset, which, as it was described in Section 2, is responsible for the in-ear recording of the natural environment as well as the reproduction of the synthesized binaural sound objects. The ARA headset audio transmitter and receiver are operating in the range of 2.4GHz, allowing high quality audio transmissions.

Figure 2 The "Eidola" user equipment

The ARA headset is integrated with a head-tracking system prototype developed using a modified computer joystick construction appropriately applied on the back part of the human head, as it is shown in Fig. 3. The angle accuracy values obtained from the head-tracking prototype exceeded the requirements of the current work, being in the range of nearly half a degree in both elevation and azimuth planes. The head-tracking output angle values were transmitted to a central controller via a wireless Bluetooth asynchronous link. After a sequence of thorough tests, it was found that the Bluetooth protocol can completely satisfy the bandwidth and latency requirements for real-time transmissions of the head-tracking data. Moreover, the Bluetooth link was also responsible for asynchronously transmitting the information that corresponds to the user button (or trigger) press event.

Figure 3 The developed head-tracking system

The above described user equipment was battery operated, with a typical re-charge time interval in the range of 8 hours.

3.2. Game prototype architecture

Figure 4 illustrates the architecture of the “Eidola” ARA-game prototype. It mainly consists of the user equipment described in the previous paragraph (indicated here as the wireless system), a common computer system executing all the necessary software modules and a digital camera. It should be noted here that all the control and signal processing methods required for implementing the Eidola prototype architecture were realized in software.

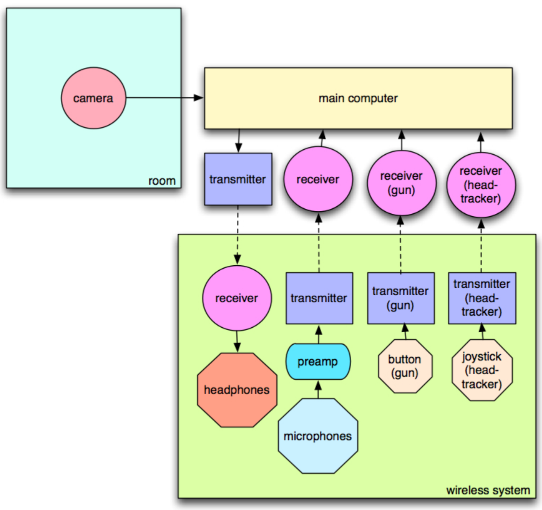

Figure 4 The “Eidola” prototype architecture

More specifically, the software modules developed during this work are the following: a) The ARA mixer, combined with a room-acoustics analysis sub-module for calculating the appropriate room impulse responses. As explained in Section 2, this module is responsible for producing the final augmented binaural signal sent to the user, taking into account the relative positions of the “Eidola” creatures and the room acoustic properties b) a user position detection module that extracts the instantaneous user position from the video signal obtained by the digital camera. The instantaneous user position is a significant parameter, not only for the game-play it-self (as it was mentioned previously, the user can defeat an “Eidola” creature when his/her position coincides with its position), but also for determining the instantaneous room impulse responses. c) a sound synthesis module which produces the virtual sound objects that correspond to each one of the “Eidola” creatures. For the purposes of this work, a number of sound synthesis techniques were tested for selecting the most appropriate one in terms of optimizing the ability of the user to discriminate them in the 3D space and in the frequency domain. d) The “Eidola” movement trace scheduler, which is responsible for algorithmically moving the “Eidola” creatures in three dimensions, taking into account the presence and the boundaries of the real-world objects that exist within the game environment. The communication between all the above software modules was realized using the well known Open Sound Control (OSC) protocol [14].

4. IMPLEMENTATION AND RESULTS

The “Eidola” ARA-game prototype installation was realized and demonstrated during the 3rd annual audiovisual festival organized by the department of Audiovisual Arts, Ionian University on May, 2009. The “Eidola” interactive environment was installed in a room with dimensions equal to 4x4x3.5 meters. A video-camera required for detecting the instantaneous participant position was hidden and placed at the center of the roof. The main computer was also installed in an isolated part of the inner roof structure, allowing a cable-free view of the installation. An LCD monitor (Fig. 5) was placed next to the installation entrance, displaying the “Eidola” logo and the total achieved user score.

Figure 5 The LCD monitor screen

Figure 6 illustrates the real-world objects placed within the installation space for the purposes of the “Eidola” prototype demonstration. The selection of these objects was based on their influence to the overall atmosphere of the game and their relevance to the game-play. Moreover, the impact of these objects as the principal visual component of the game was enforced by appropriate coloring and lighting of the installation room. The exact placement of these objects in 3D space was registered into the software modules (i.e. the "Eidola" trace movement scheduler and the room acoustic analysis module) and was not allowed to be changed during the demonstration session.

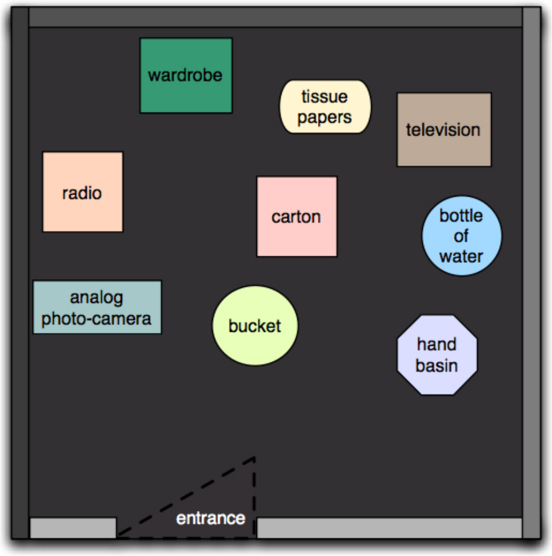

Figure 6 Placement of the real-world objects used

The aim of demonstrating the "Eidola" game prototype was twofold: a) to preliminarily investigate the efficiency of ARA as a global mean and framework for realizing complicated and/or advanced audio-based game scenarios and b) due to the overall system complexity, to indicate and overcome all the difficulties imposed by the implementation and integration of all the software and hardware modules involved (such as the presence of electromagnetic interference, heat dissipation and sound isolation).

Focusing on implementation issues, a typical example of a problem raised is the employment of the Bluetooth protocol: A major drawback of using it for the transmission of the head-tracking output as well as the trigger press event was the concurrent usage of the 2.4GHz frequency band by the audio transmission/reception equipment, which imposed some audible distortions artifacts (typically in terms of short audio transmission gaps and relative playback "clicks"). However, during the "Eidola" demonstration it became evident that the perceptual level of these distortions was low (probably because of the frequency-hopping Bluetooth transmission and retransmission mechanisms employed) and it did not affect the game-play.

Focusing on some subjective observations obtained during the "Eidola" prototype demonstration, more than 50 users entered the installation and played (Fig. 7). In all user cases the general impression was that the installation environment was suitable for accurately reproducing the game-play atmosphere. Moreover, especially for the augmented 3D sound component, the users that were not familiar with binaural technology found it fascinating, while experienced users (and some invited audio technology experts) found it realistic and accurate. It should be mentioned here that the latter user category achieved higher scores, a well expected result also observed in many psychoacoustic experiments.

Figure 7 Eidola ARA-game demonstration

Apart from the positive mean general impression, the following observations and trends were obtained: a) The user equipment on-body installation and usage was found to be acceptable, although it somehow restricted the human movements (and particularly walking) within the installation, especially at the very beginning of a game session b) despite the relatively simple game-play, the majority of the users tried to extend the scenario according to the general audio-visual perception they created during their participation. After a number of discussions with these players, it was concluded that this scenario extension was raised by the complexity and harmonic integrity of the audio and visual augmented environment that triggered the players' imagination c) the presentation of the score on the LCD monitor enhanced the competitive character of the game: many users played more than once in order to improve their score. The latter observation denotes the rapid adaptation of the majority of the users/players to the augmented environment, which allowed accepting it as an advanced type of a computer game.

5. CONCLUSIONS

The widespread advent of innovative digital audio technologies and concepts, such as Augmented Reality Audio (ARA) is provisioning new forms of applications. This work represents an initiative proposal which aims to combine ARA with the audio-games concept, in order to allow the development of advanced game-play scenarios where sound represents the fundamental media component. In order to assess several implementation issues and obtain a measure of the effectiveness of the above technology combination, an ARA-game prototype was realized termed as “Eidola”, which employs most of the ARA techniques and methods proposed already in the literature. It was shown that the development of ARA-games is a demanding task, since it requires the efficient integration of several different sub-systems and modules. On the other hand, the demonstration of the “Eidola” ARA-game has also proved that ARA-games represent a very interesting alternative for audiovisual and game industry.

It is the authors’ near future intention to further exploit the derived results and conclusions of this work for developing more complicated ARA-games by providing more flexible means of user interaction. Typical further developments can include mobile ARA-games taking place in partially-controlled outdoor environments.

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